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Comprehensive Report to Congress Clean Coal Technology Program

Cement Kiln Flue Gas Recovery Scrubber

A Project Proposed By Passamaquoddy Tribe

November 1989

U.S. Department of Energy
Assistant Secretary for Fossil Energy
Office of Clean Coal Technology
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1.0 EXECUTIVE SUMMARY

In December 1987, Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million to conduct cost-shared Innovative Clean Coal Technology (ICCT) projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. To that end, a Program Opportunity Notice (PON) was issued by the Department of Energy (DOE) in February 1988, soliciting proposals to demonstrate technologies that were capable of being commercialized in the 1990's, were more cost effective than current technologies, and were capable of achieving significant reduction of sulfur dioxide (SO_2) and/or nitrogen oxides (NO_x) emissions from existing coal-burning facilities, particularly those that contribute to transboundary and interstate pollution.

In response to the PON, fifty-five proposals were received by the DOE in May 1988. After evaluation, sixteen projects were selected for funding. These projects involve both advanced pollution control equipment that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating-plant capacity and extend the operating life of the facility.

One of the sixteen projects selected for funding is a project proposed by the Passamaquoddy Tribe to demonstrate an innovative technology that removes sulfur dioxide (SO_2) from cement kiln flue gas, utilizing the waste dust as a scrubbing reagent while making it suitable for recycle to the cement kiln. Approximately 90% of the sulfur will be removed from the flue gas entering the new scrubber cleaning system. Because some SO_2 is also removed by the solids in the cement kiln, the overall sulfur dioxide removal for the cement plant is expected to exceed 96%.

If successful, this demonstration would establish that the innovative technology, the Recovery Scrubber, can provide a cost-effective method of reducing SO_2 emissions from cement kilns while providing a means to recycle waste kiln dust to the cement-making process. This ability to use what is now a waste dust conserves kiln feed material and eliminates the need for landfill space.

Currently, kiln dust, high in calcium and potassium compounds, is removed from the flue gas by a dust collector and hauled to a landfill. In the process to be demonstrated by this project, this dust is mixed with water to form a slurry. The flue gas is bubbled through the slurry, and the SO_2 reacts with the potassium compounds to form potassium sulfate (K_2SO_4). Because the K_2SO_4 is more soluble than the calcium compounds that are in the slurry, the calcium compounds are allowed to settle from the K_2SO_4 solution and are returned to the kiln feed system, while an evaporation process is used to produce dry K_2SO_4 and distilled water by-products.

The demonstration project will be conducted at the Dragon Products Company's cement plant located in Thomaston, Knox County, Maine. This plant was formerly owned by the Passamaquoddy Tribe, and the new owner has agreed to use the plant in this project and is providing cost sharing. Its location is shown in Figure 1. The host cement plant is considered to be a large commercial cement plant.

The project will be performed over a 36 month period. The total estimated cost is $10,165,916, of which $4,786,074 will be provided by DOE, and the balance will be supplied by the Dragon Products Company and the Passamaquoddy Tribe. The heat exchanger/crystallizer will be designed and supplied by HPD, Inc. The E.C. Jordan Company will provide overall engineering and design services to the project.

2.0 INTRODUCTION AND BACKGROUND

The domestic coal resources of the United States play an important role in meeting current and future energy needs. During the past 15 years, considerable effort has been directed to developing improved coal combustion, conversion, and utilization processes to provide efficient and economic energy options. These technology developments permit the use of coal in a cost-effective and environmentally acceptable manner.

2.1 Requirement for Report to Congress

In December 1987, Congress made funds available for the ICCT Program in Public Law No. 100-202, "An Act Making Appropriations for the Department of Interior and Related Agencies for the Fiscal Year Ending September 30, 1988, and for Other Purposes" (the "Act"). This Act provided funds for the purpose of conducting cost-shared clean coal technology projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities, and authorized DOE to conduct the ICCT Program. Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million which will remain

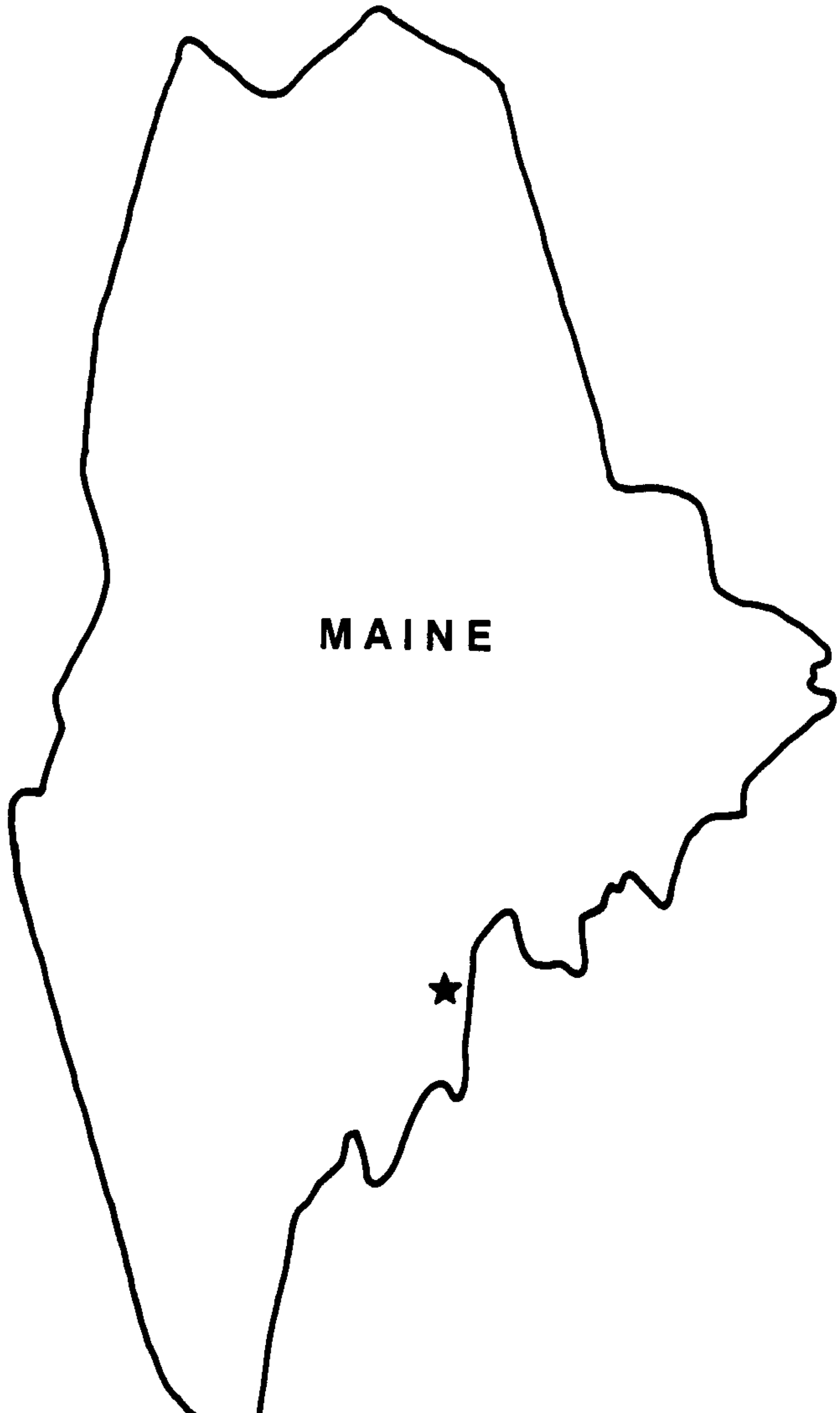

FIGURE 1. RECOVERY SCRUBBER FOR CEMENT KILN RETROFIT APPLICATION AT AN INDUSTRIAL SITE (THOMASTON).

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available until expended, and of which (1) $50,000,000 was available for the fiscal year beginning October 1, 1987; (2) an additional $190,000,000 was available for the fiscal year beginning October 1, 1988; (3) an additional $135,000,000 will be available for the fiscal year beginning October 1, 1989; and (4) $200,000,000 Will be available for the fiscal year beginning October 1, 1990. Of this amount, $6.782 million will be set aside for the Small Business and Innovative Research Program, and is unavailable to the ICCT Program.

In addition, after the projects to be funded had been selected, DOE prepared a comprehensive report on the proposals received. The report was submitted in October 1988 and was entitled "Comprehensive Report to Congress: Proposals Received in Response to the Innovative Clean Coal Technology Program Opportunity Notice" (DOE/FE-0114). Specifically, the report outlines the solicitation process implemented by DOE for receiving proposals for ICCT projects, summarizes the project proposals that were received, provides information on the technologies that are the focus of the ICCT Program, and reviews specific issues and topics related to the solicitation.

Public Law No. 100-202 directed DOE to prepare a full and comprehensive report to Congress on any project to receive an award under the ICCT Program. This report is in fulfillment of this directive and contains a comprehensive description of the Recovery Scrubber Demonstration Project.

2.2 Evaluation and Selection Process

The DOE issued a PON on February 22, 1988, to solicit proposals for conducting cost-shared ICCT demonstrations. Fifty-five proposals were received. All proposals were required to meet the six qualification criteria provided in the PON. Failure to satisfy one or more of these criteria resulted in rejection of the proposal. Proposals that passed Qualification Review proceeded to Preliminary Evaluation. Three preliminary evaluation requirements were identified in the PON. Proposals were evaluated to determine whether they met these requirements; those proposals that did not were rejected.

Of those proposals remaining in the competition, each offeror's Technical Proposal, Business and Management Proposal, and Cost Proposal were evaluated. The PON provided that the Technical Proposal was of somewhat greater importance than the Business and Management Proposal and that the Cost Proposal was of minimal importance; however, everything else being equal, the Cost Proposal was very important.

The Technical Evaluation Criteria were divided into two major categories. The first, "Commercialization Factors," addressed the projected commercialization of the proposed technology. This was different from the proposed demonstration project itself and dealt with factors involved in the commercialization process. The criteria in this section provided for consideration of (1) the potential of the technology to reduce total national emissions of SO_2 and/or NO_x and to reduce transboundary and interstate air pollution with minimal adverse environmental, health, safety, and socioeconomic (EHSS) impacts; and (2) the potential of the proposed technology to improve the cost effectiveness of controlling emissions of SO_2 and NO_x when compared to commercially available technology options.

The second major category, "Demonstration Project Factors," recognized the fact that the proposed demonstration project represents the critical step between "predemonstration" scale of operation and commercial readiness, and dealt with the proposed project itself. Criteria in this category provided for consideration of the following: technical readiness for scale-up; adequacy and appropriateness of the demonstration project; the EHSS and other site-related aspects; the reasonableness and adequacy of the technical approach, and the quality and completeness of the Statement of Work.

The Business and Management Proposal was evaluated to determine the business and management performance potential of the offeror, and was used as an aid in determining the offeror's understanding of the technical requirements of the PON. The Cost Proposal was reviewed and evaluated to assess the validity of the proposer's approach to completing the project in accordance with the proposed Statement of Work and the requirements of the PON.

Consideration was also given to the following program policy factors:

(1) The desirability of selecting projects for retrofitting and/or repowering existing coal-fired facilities that collectively represent a diversity of methods, technical approaches, and applications (including both industrial and utility);

(2) The desirability of selecting projects that collectively produce some near-term reduction of transboundary transport of emitted SO_2 and NO_x; and

(3) The desirability of selecting projects that collectively represent an economic approach applicable to a combination of existing facilities that significantly contribute to transboundary and interstate transport of SO_2 and NO_x in terms of facility types and sizes, and coal types

The PON also provided that, in the selection process, DOE would consider giving preference to projects located in states where the rate-making bodies of those states treat innovative clean coal technologies the same as pollution control projects or technologies. The inclusion of this project selection consideration was intended to encourage states to utilize their authorities to promote the adoption of innovative clean coal technology projects as a means of improving the management of air quality within their areas and across broader geographical areas.

The PON provided that this consideration would be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects received identical evaluation scores and remained essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

An overall strategy for compliance with the National Environmental Policy Act (NEPA) was developed for the ICCT Program, consistent with the Council on Environmental Quality NEPA regulations and the DOE guidelines for compliance with NEPA. This strategy includes both programmatic and project-specific environmental impact considerations during and subsequent to the selection process.

In light of the tight schedule imposed by Public Law No. 100-202 and the confidentiality requirements of the competitive PON process, DOE established alternative procedures to ensure that environmental factors were fully evaluated and integrated into the decision-making process to satisfy its NEPA responsibilities. Offerors were required to submit both programmatic and project-specific environmental data and analyses as a discrete part of each proposal submitted to DOE.

The DOE strategy for NEPA compliance has three major elements. The first involves preparation of a programmatic environmental impact analysis for public distribution, based on information provided by the offerors and supplemented by DOE, as necessary. This environmental documents that relevant environmental consequences of the ICCT Program and reasonable programmatic alternatives are considered in the selection process. The second element involves preparation of a pre-selection project-specific environmental review for internal DOE use. The third element provides for preparation by DOE of site-specific documents for each project selected for financial assistance under the ICCT Program.

No funds from the ICCT Program will be provided for detailed design, construction, operation, and/or dismantlement until the third element of the NEPA process has been successfully completed. In addition, each Cooperative Agreement entered into will require an Environmental Monitoring Plan to ensure that significant technology-, project-, and site-specific environmental data are collected and disseminated.

After considering the evaluation criteria, the program policy factors, and the NEPA strategy, sixteen proposals were selected for negotiation and award. The proposal submitted by the Passamaquoddy Tribe was one of these proposals.

3.0 TECHNICAL FEATURES

3.1 Project Description

The Passamaquoddy Tribe's project will demonstrate the feasibility of desulfurizing the flue gas from a coal-fired cement kiln and recycling the dust recovered from the kiln. This process concept has been demonstrated on a pilot scale, and this project will be the first commercial-scale demonstration of the technology. This Recovery Scrubber technology uses as the scrubbing medium a solution/slurry of dust recovered from the kiln flue gas. This dust, which is relatively high in potassium oxide (K_2O), is contacted with the flue gas to remove the SO_2. Subsequent process steps recover these products: potassium sulfate (K_2SO_4), a solid rich in calcium for recycle to the kiln, and distilled water.

This project is intended to demonstrate a process that removes over 90% of the SO_2. Also, some NO_x and CO_2 may be removed from the cement kiln flue gas. No chemicals, other than the available waste kiln dust, are required for the process. By using the waste dust to remove SO_2, a waste disposal problem is eliminated and the kiln feed materials are more efficiently utilized while producing valuable K_2SO_4.

The project will take place at the Dragon Products Company in Thomaston, Knox County, Maine. This cement kiln produces approximately 470,000 tons of cement per year and uses approximately 90,000 tons of eastern bituminous coal with a sulfur content between 2.5 and 3.0 percent.

3.1.1 Project Summary

Project Title:	Passamaquoddy Innovative Clean Coal Technology Program
Proposer:	The Passamaquoddy Tribe
Project Location:	Thomaston, Maine Knox County
Technology:	Recovery Scrubber
Application:	Retrofit to Cement Kiln
Types of Coal Used:	Eastern High-Sulfur Bituminous
Product:	Environmental Control/Waste Recovery Technology
Project Size:	270 Tons Per Day Coal Feed with 1424 Tons Per Day Kiln Product
Project Start Date:	April 1989
Project End Date:	September 1992

3.1.2 Project Sponsorship and Cost

Project Sponsor:	Passamaquoddy Tribe	
Co-Funders:	U.S. Department of Energy Dragon Products Company	
Estimated Project Cost:	$10,165,916	
Project Cost Distribution:	Participant Share(%)	DOE Share(%)
	52.92	47.08

3.2 Cement Kiln Flue Gas Recovery Scrubber Process

3.2.1 Overview of Process Development

The Dragon Products Company cement plant produces 10.4 tons per hour of waste kiln dust. Since potassium and sodium compounds tend to volatilize at the hot (2600 degrees Fahrenheit) end of the kiln and condense as fine dust at the cooler exhaust end of the kiln, the waste kiln dust is too high in potassium and sodium to reuse directly in the kiln feed. At the Dragon Products Company cement plant, the nature of the kiln feedstock is such that K_2O is the problem.

The Recovery Scrubber technology was developed while seeking a method to reduce the potassium content of the kiln dust. Part of the Dragon Products Company's solution to this problem is to contact the dust with the kiln flue gas to recover the potassium as potassium sulfate while removing most of the SO_2. Research by the Dragon Products Company indicates that this technology can also be applied to fossil-fuel-fired-utility, waste-to-energy, and certain other industrial flue gas streams by substituting biomass ash for kiln dust as the source of potassium. The potassium sulfate formed can be sold for use as a fertilizer.

The developmental work was done on a 2000 cubic feet per minute slipstream from the kiln at the same cement plant where this demonstration project will be conducted. The pilot plant for the slipstream consisted of cooling the kiln gas from 300 degrees Fahrenheit (°F) to 130 °F. A blower was used to bubble the cooled gas through the slurry in the reaction tank, where more than 90% of the incoming SO_2 was removed. A settling tank was used to separate the suspended solids (mostly calcium compounds and silicates) from the potassium sulfate solution, which was further processed to produce potassium sulfate crystals and distilled water, which are the two by-products from this SO_2 removal process.

The next and final stage in the development of the Recovery Scrubber is the *installation and operation of the process on a commercial cement kiln. This* demonstration project is the final proof of the Recovery Scrubber's technical and economic viability.

3.2.2 Process Description

Cement is produced by heating a mixture of minerals to promote chemical reactions and to fuse the product into clinker which is then crushed and sold. The principal mineral used in cement production is limestone consisting mostly of calcium carbonate ($CaCO_3$). Other minerals fed to the process are clay, sand, and iron ore. The feed materials sent to cement plants include salts of sodium and/or potassium. The quantity of potassium and sodium compounds, permitted by product specifications, is very limited.

The mixture of feed minerals is heated in a kiln. The kiln is a 200-foot long refractory-lined, cylindrical vessel that is elevated at one end to create a modest slope. The entire vessel slowly rotates to mix the contents. The feed (dry or a dense slurry) is fed into the elevated end. A burner is located at the opposite end, and the combustion products pass through the kiln to heat the feed materials. The exhaust gases exit the kiln, carrying along a quantity of dust. Because the burner end of the kiln operates at very high temperatures, some of the potassium and sodium salts are vaporized and condense as oxides in the form of a fine dust in the cooler part of the kiln. Therefore, the dust leaving the kiln is relatively high in potassium and sodium, and cannot be reused. At the Dragon Products Company kiln, high potassium levels in the dust require that this material be disposed in a landfill. Currently, the gas leaving the coal-fired kiln passes through a dust collector and enters the atmosphere through a stack.

This demonstration project will use this dust containing potassium to desulfurize the kiln flue gas and render the kiln dust suitable for recycle. In this process (Figure 2), the gas leaving the dust collector is passed through a crystallizer/

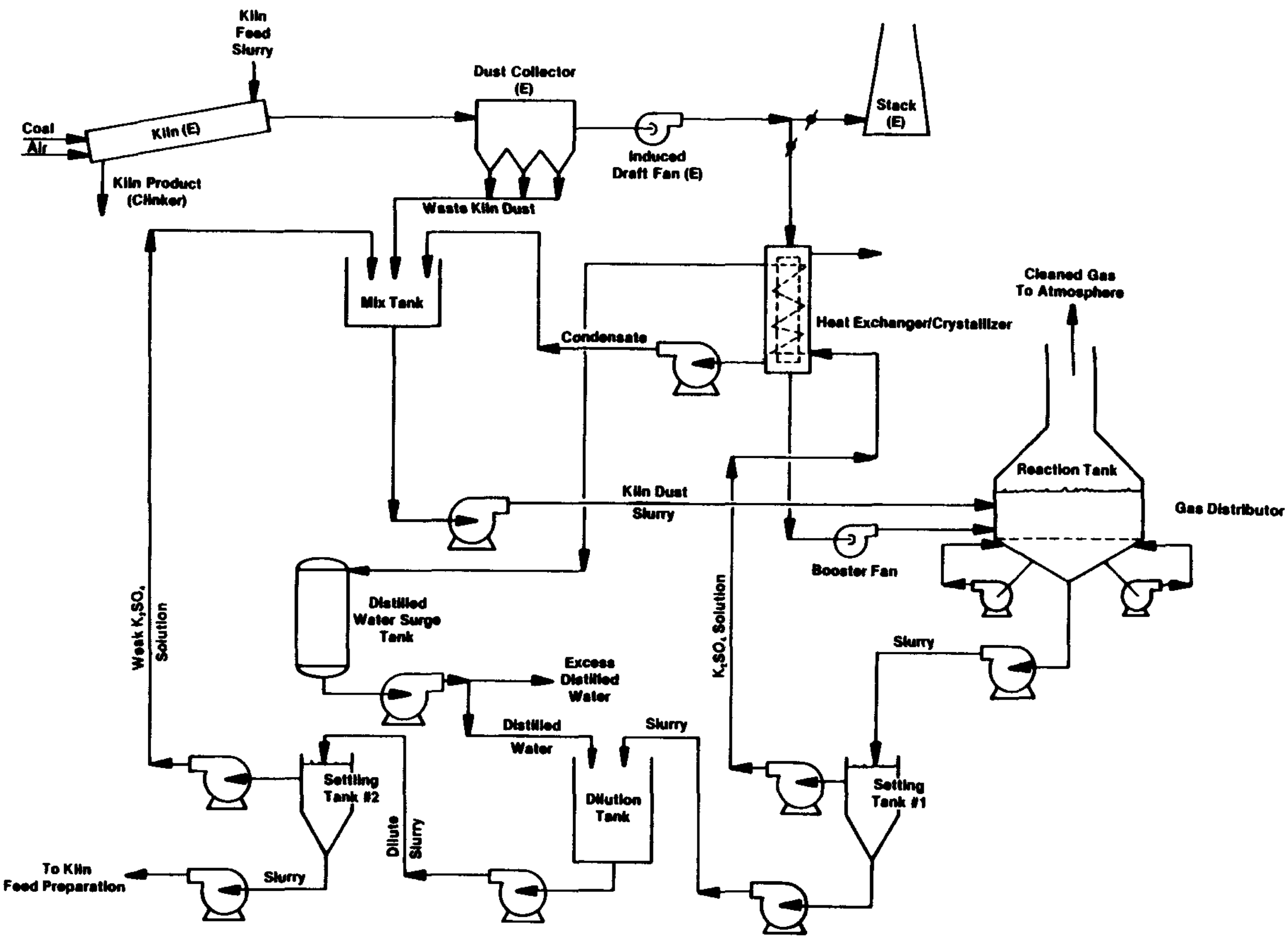

FIGURE 2. RECOVERY SCRUBBER PROCESS FLOW DIAGRAM.

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heat exchanger, which cools the gas, condensing some water vapor from it. The heat removed from the gas is used elsewhere in the process as will be described later.

The dust removed from the flue gas is transferred to the mix tank where it is combined with recycled process-derived water streams to form a slurry. This slurry is pumped to the reaction tank, which is sufficiently large to allow a fourteen-hour liquid-retention time. The kiln flue gas that was cooled in the crystallizer/heat exchanger is bubbled through the slurry. In the aqueous phase, the potassium oxide reacts with the SO_2 in the gas to form K_2SO_4 through a series of chemical reactions. The desulfurized flue gas leaves the reaction tank and enters the atmosphere.

A slurry is continuously removed from the bottom of the reaction tank and pumped to settling tank No. 1. The slurry consists of a potassium sulfate solution with suspended calcium and silicon solids--primarily calcium carbonate. The settler supernatant solution is pumped to the heat exchanger/crystallizer. The settled solids are pumped to the dilution tank and mixed with a quantity of process-derived distilled water to dissolve or wash any potassium sulfate carried along with the solids. The material leaving the dilution tank is pumped to settling tank No. 2, and the dilute supernatant K_2SO_4 solution is recycled to the mix tank to prepare the kiln dust slurry as described previously. The settled bottom material, rich in calcium carbonate is pumped back to the kiln feed preparation area for recycle to the kiln.

The solids-free potassium sulfate solution pumped from settling tank No. 1 is first heated by indirect heat exchange with the flue gas in the heat exchanger/crystallizer. The hot solution is then fed to a flash tank in the evaporation section, where, by flashing, a portion of the water is evaporated and simultaneously the K_2SO_4 solution is cooled. The combination of evaporation and cooling results in crystals of potassium sulfate. These are removed from the remaining solution, dried, and sold as the major by-product. The water vapor leaving the flash tank is condensed. A portion of this distilled water is recycled to the dilution tank as described earlier, and the excess is sold as a by-product.

In summary, this process uses waste kiln dust and waste heat to desulfurize the kiln flue gas. In the process, it renders the kiln dust suitable for reuse in the kiln, thus conserving raw feed supplies and landfill space while producing two valuable by-products -- potassium sulfate and distilled water. There is no waste produced by the process.

3.2.3 Application of Process in Proposed Project

This project is intended to demonstrate the technical, environmental, and economic viability of desulfurizing the cement kiln flue gas using the solid waste product from the cement-making process. It will also demonstrate the marketability of the by-products-- distilled water and potassium sulfate. This project will result in the installation of the recovery scrubber and all ancillary equipment in the Dragon Products Company cement plant located in Thomaston, Maine. It will be a fully commercial size installation and will include all the equipment that will be part of future commercial installations.

This project will demonstrate the ability of the process to successfully remove over 90% of the SO_2 from the kiln gas. In addition, the level of NO_x and CO_2 removal will be determined. This project will also demonstrate the ability of the process to make the kiln dust suitable for reuse in the cement-making process. Therefore this project will demonstrate all applicable performance, equipment, and cost factors for this scrubber technology.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As with any new technology, some element of risk exists. However, as described earlier, this process was developed on a pilot scale using the flue gas and dust from the cement plant where this demonstration will take place. The equipment used and type of materials handled are similar in nature to those found in alkali-based systems currently available for scrubbing the flue gas from power plants. Therefore, it is believed that the technical risks associated with this project are resolvable with appropriate design and operating considerations.

Recognized potential problem areas include corrosion, erosion, and scaling (deposition of solids) of equipment. Changes in the coal sulfur levels and/or the composition of the feed materials may lead to an imbalance in the quantities of potassium and sulfur dioxide. Potential operating and equipment problems can be remedied by systems engineering, careful selection of materials for construction, and/or modification of operating procedures.

3.3.1.1 Similarity of Project to Other Demonstration/Commercial Efforts

Many processes use an alkali-based wet scrubbing system to remove SO_2 from flue gas. The majority are based on solutions or slurries of calcium compounds. A lesser number of the wet processes use magnesium- or sodium-based systems, and a few use combinations of these alkalis. The alkali-based wet FGD systems range from those that are fully commercial to those in the early stages of development. The bulk of these processes produce a sludge that requires disposal facilities, and all require that the reagents be purchased.

There are a few other potassium-based systems, but these are in the early stages of development, and none of them are believed to be ready for a commercial demonstration. A common problem for these systems is that potassium is a relatively expensive material. Therefore, regenerable systems are required to minimize the costs of potassium compounds. Regeneration facilities typically result in a more complex plant that is more expensive than some of the "throwaway" processes.

The technology developed by the Passamaquoddy Tribe uses a process-derived potassium-bearing waste material for its scrubbing solution, thus eliminating a major expense with the other potassium-based systems. In addition, the Recovery Scrubber is ready for commercial demonstration, unlike other potassium-based processes that are in early stages of development.

3.3.1.2 Technical Feasibility

This process evolved from efforts to make the kiln dust suitable for recycle to the kiln. The method that was developed was to pass flue gas through a slurry of kiln dust to remove the potassium as potassium sulfate, thus removing the sulfur dioxide from the flue gas. Pilot-plant tests verified the chemical reactions that remove the sulfur dioxide from the flue gas. The pilot-plant tests also verified the ability of the process to render the kiln dust suitable for recycle to the kiln feed, and product analysis confirmed the value of the by-product potassium sulfate. The heat and material balances were also confirmed through the pilot-plant tests and subsequent engineering analysis.

Although the flue gas feed rate to the pilot plant was only 2000 cubic feet per minute (CFM), all equipment used in the demonstration project is of the size and type used in commercial operation. The types of materials handled in this process have properties similar to other materials that are routinely handled.

The pilot plant data, coupled with experience in handling similar materials in other operations, indicate that this process is technically sound and should not present any unusual problems in the demonstration project or future commercial installations.

3.3.1.3 Resource Availability

As previously discussed, no raw materials are required for this process. The kiln dust used to remove SO_2, NO_x, and CO_2 from the gas is a currently available waste product, which, owing to its high pH, requires a secure landfill for its disposal. Water used in the process is condensed from the gas and is recycled. The amount of coal required to heat the kiln will remain unchanged. Limestone feed to the kiln will be reduced by the quantity of kiln dust that is recycled. Excess distilled water will be sold or discharged. This process not only requires no additional resources but actually conserves raw feedstock and landfill space while producing clean water and fertilizer from waste materials.

Since no additional raw materials are required for this process, the existing transportation infrastructure will not be affected. Construction and operating personnel are available in the site vicinity, and staffing for the project should have no major impact on the surrounding communities.

The only major utility requirement for this plant is electricity for the fan and pump motors. This requirement is not expected to create any problem for the area's electric supply.

Space for the demonstration project is readily available at the Dragon Products Company cement plant.

In summary, this project will require only modest resources, all of which are readily available.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

This demonstration project will clean the kiln flue gas from a cement plant that produces approximately 470,000 tons per year of product clinker while burning approximately 90,000 tons per year of coal. This is a fully commercial-scale cement plant that is larger than average. Therefore, no additional scale-up is required for installation of the Recovery Scrubber at the majority of cement plants.

3.3.3 Role of the Project in Achieving Commercial Feasibility of the Technology

This project represents the opportunity to demonstrate a technology that utilizes a process-derived waste to remove 90% of the SO_2, and some NO_x and CO_2, from the flue gas while rendering the waste suitable for recycle to the host process and producing a valuable by-product. This unique process therefore helps reduce SO_2, NO_x, and CO_2 emissions;, conserves natural resources; and eliminates the need for landfill space associated with the operation of a cement plant. By doing so, it promotes the use of domestic high-sulfur coal in an environmentally beneficial manner.

3.3.3.1 Applicability of the Data to be Generated

Environmental data to be collected includes emission rates for SO_2, NO_x, and CO_2. This will be coupled with measurement of the SO_2, NO_x, and CO_2 in the exhaust prior to scrubbing so that removal efficiency can be evaluated. Both of these sets of measurements will be made continuously by on-line monitors. The cement plant currently measures SO_2 emissions. The measurement system continuously samples the exhaust stream. The SO_2 concentration in parts per million is recorded on a strip-chart recorder. This data stream is sampled by the computer every 10 seconds and recorded as one-hour averages. The one-hour averages are recorded also to obtain daily averages. Those daily averages are recorded to obtain the 90-day average on which the license emission limit is based. A system that operates the same way is planned for the before-scrubbing and after-scrubbing measurements discussed above. If distilled water is discharged, it will be monitored to maintain quality. Process flows will be monitored. The total amount of kiln dust recycled to the kiln plays a big part in determining the overall economics of the system, as does the sale of the potassium sulfate. These flows will be recorded for use in commercialization.

The data obtained during operation will provide information for optimization of material flows throughout the system. The water used in processing, however, may need to be increased or decreased to minimize operating cost for pumps and to assure adequate SO_2 removal. Furthermore, operating data will generate information needed for the design of future systems and components, which is essential for the commercialization effort.

Economic assessment of the system will be based on comparison of initial cost and annual operating cost with the savings and income generated by use of the process. Installation cost will be known at the time of start-up. Operating cost will be obtained by recording labor and maintenance expenditures as they occur. Energy cost will be for electricity only and will be available on a monthly basis.

The operating, environmental, and economic data obtained will allow the technology to be fully optimized and will support the commercialization of the technology.

3.3.3.2 Identification of Features That Increase Potential for Commercialization

The Recovery Scrubber has a number of features that increase its potential for commercialization. One is that the sulfur removal efficiency, greater than 90 percent, is as good as, or better, than that of most other scrubbers. In addition, the process does not require purchase of any material as scrubber reactant. The available waste kiln dust is fully sufficient for that use. Another feature that increases the potential for commercialization of the Recovery Scrubber is the absence of scrubber waste sludge for disposal. All of the unused scrubber reactants are recycled. The insoluble recycled solids are all useful as cement kiln raw feed and will be totally consumed in the cement-making process. The liquid carrying the dissolved alkali sulfates is used as the coolant in the flue-gas-cooling step. The alkali sulfates are crystallized for recovery and sale as fertilizer or chemical plant feedstock. The evaporated water is condensed as distilled water, which may be used as makeup water, sold, or discharged. Distilled water can be discharged under a current permit.

A major additional feature of the Recovery Scrubber is that operation of the system provides income. There is no net cost of operation. Adequate scrubbing allows use of higher sulfur content, lower cost fuels. Recovery of the former waste kiln dust as raw feed not only decreases the requirement for production of stone from quarrying operations but eliminates both the need for landfill disposal of the waste dust and the environmental problems resulting from leachate from that waste. Most important to the economics of the process are (1) the salable by-products -- potassium sulfate and distilled water-- whose value is estimated to exceed the combined value of the recovered feedstock, and (2) reduced environmental costs.

While each of these features increases the potential for commercialization, the combination of these features puts the Recovery Scrubber in a very attractive position for commercialization following a successful demonstration.

3.3.3.3 Comparative Merits of the Project and Projection of Future Commercialization and Market Acceptability

The site selected to demonstrate the Recovery Scrubber is at a cement plant that is currently operating. Adequate space is available at the plant site, and the owners are fully committed to the project. The owner of the process, the Passamaquoddy Tribe, is fully committed to the project and to expanding the use of the Recovery Scrubber in other cement plants and to extending its use to the utility industry.

The successful demonstration of the Recovery Scrubber technology will result in an effective means of removing SO_2 from cement kiln flue gas while creating no new environmental problems, such as waste sludge.

This project will also demonstrate whether the value of the by-products more than offsets its operating cost, thus creating a positive overall cash flow for cement plants. The vast majority of environmental control technologies increase operating costs. Therefore, if this demonstration is successful, it is expected that the Recovery Scrubber will be very acceptable to cement industry because it will solve two environmental problems (emissions and solid waste) while creating additional income for their plants. Evidence of this technology's acceptability to the cement industry is provided by the fact that, although no longer owned by the Passamaquoddy Tribe, the Dragon Cement Company has made the site available for this project and has also agreed to provide $4,500,000 toward this project.

4.0 ENVIRONMENTAL CONSIDERATIONS

The overall strategy for compliance with NEPA, cited in Section 2.2, contains three major elements. The first element, the programmatic environmental impact analysis (PEIA), was issued as a public document in September 1988. In the PEIA, the Regional Emission Database and Evaluation System (REDES) model developed by DOE's Argonne National Laboratory was used to estimate the environmental impacts expected to occur in the year 2010 if each innovative clean coal technology were to reach full commercialization and captured 100 percent of its applicable market. The environmental impacts were compared to the no-action alternative under which it was assumed that use of conventional coal technologies continues through 2010 with new plants using conventional flue gas desulfurization controls to meet New Source Performance Standards.

The expected performance characteristics and applicable market of the proposed cement kiln gas recovery scrubber were used to estimate the environmental impacts that might result if this technology were to reach full commercialization. There are over 250 cement kiln installations in the United States and along the St. Lawrence River in Canada emitting approximately 230,000 tons/year of SO_2. Based upon the characteristics of the technology, the applicable market would include approximately 75% of these installations. If the technology were installed in the applicable market facilities, the SO_2 emissions could be reduced by approximately 150,000 tons/year. The effect on NO_x emissions will be determined during the demonstration. Some reduction in NO_x emissions is expected. The waste dust that previously would have been landfilled would be recovered for recycle to the kiln and to produce by-product fertilizer. Essentially, the solid waste stream would be eliminated through recovery. Water usage may or may not increase depending upon the configuration of the existing kiln facility. However,the quality and amount of waste water will be respectively improved and reduced because the technology will produce distilled water for either sale or discharge.

The second element of DOE's NEPA strategy for the ICCT program involved preparation, for internal DOE use only, of a preselection project-specific environmental review based on project-specific environmental data and analyses that the offeror supplied as a part of each proposal. This review contained a discussion of the site-specific environmental, health, safety, and socioeconomic (EHSS) issues associated with the demonstration project. It included a discussion of the advantages and disadvantages of the proposed site and process. A discussion of the environmental impacts of the proposed project on the existing environment, and a list of the permits that must be obtained to implement the proposal, were included. It also contained options for controlling discharges and management of solid and liquid wastes. Finally, the risks and impacts of the proposed project were assessed. Based on the information available during selection and pre-award, no EHSS issues have been identified that would predict any significant adverse environmental impacts resulting from construction and operation of the proposed cement kiln gas recovery scrubber.

As the third element of the NEPA strategy, the Participant (Passamaquoddy Tribe) has submitted the environmental information specified in Appendix J of the PON. This detailed site- and project-specific information will be used as the basis for the development of the NEPA documents to be prepared by DOE. These documents will be completed and approved in full conformance with the requirements of the CEQ regulations (40 CFR Parts 1500-1508) and DOE guidelines (52 FR 47662-4767) before federal funds are provided for detailed design, construction, and operation.

Discussions with the Maine Department of Environmental Protection indicate that the permitting process should be completed within six months.

In addition to the NEPA requirements, the Participant must prepare and submit an Environmental Monitoring Plan (EMP). Guidelines for the development of the EMP are provided in Appendix N of the PON. The EMP is intended to ensure that significant technology-, project-, and site-specific data are collected and disseminated to provide health, safety, and environmental information should the technology be used in commercial applications.

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The Passamaquoddy Tribe has developed and owns the technology, will be the prime contractor to DOE, and, as such, will execute the Cooperative Agreement with DOE. Dragon Products Company, Inc., will provide the host site, hold title to the demonstration plant, and contribute to project funding.

The DOE will monitor the project through the Contracting Officer and the Contracting Officer's Technical Representative (COTR). The Participant will manage the project through a working group comprising two tribal representatives and two Dragon Products representatives. This group will be chaired by a representative of the Passamaquoddy Tribe, who will also serve as Program Manager. The Program Manager will be assisted by a team of technical and managerial personnel from several organizations.

A multi-organization team (Figure 3) headed by the working group will be involved in this project. In addition to the Passamaquoddy Tribe and Dragon Products Company, other members of the team are the E.C. Jordan Company, an engineering company; HPD, Incorporated, the supplier of the heat exchanger/crystallizer unit; and Cianbro Corporation, the general contractor.

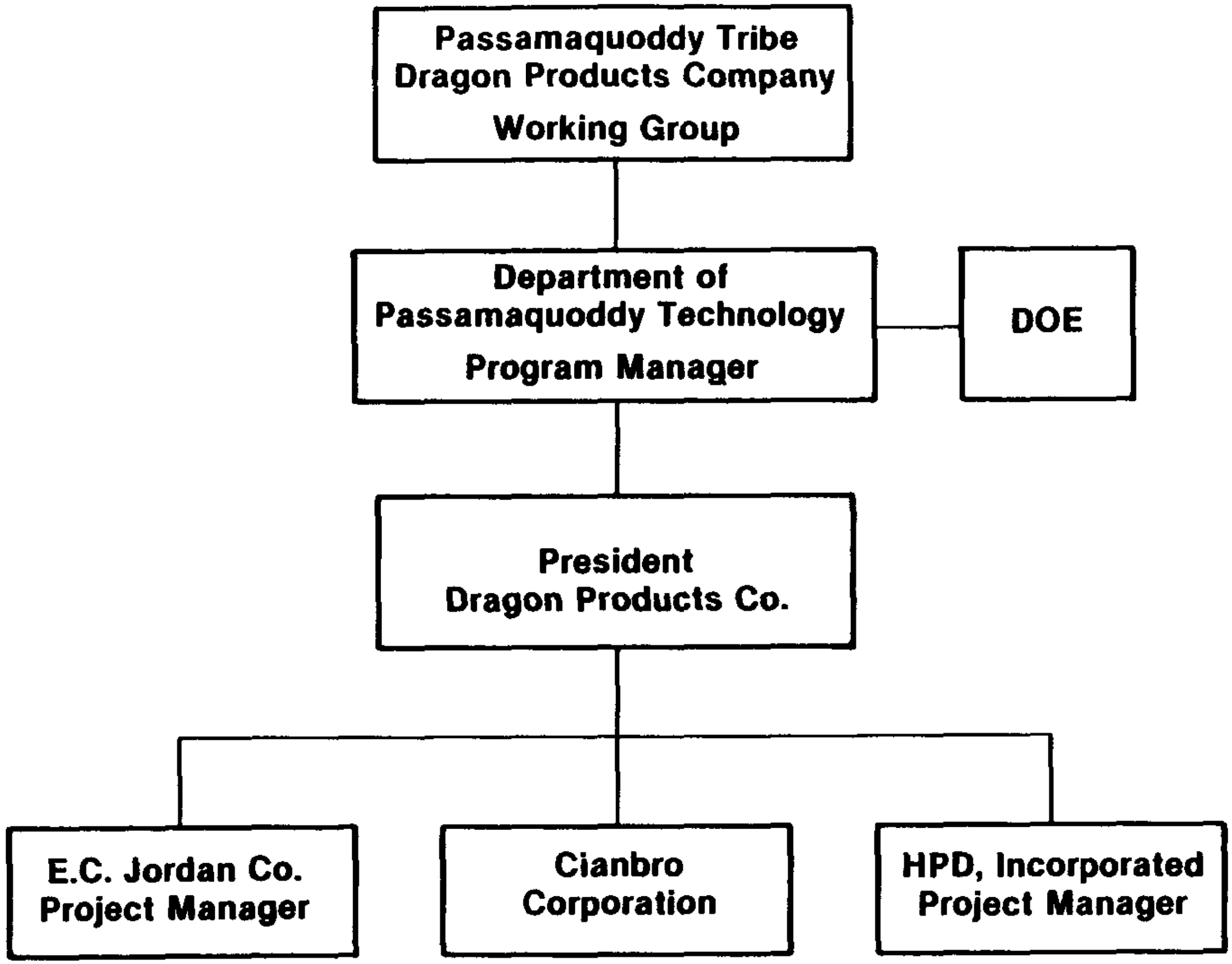

FIGURE 3. ORGANIZATION CHART FOR THE PASSAMAQUODDY TRIBE CLEAN COAL TECHNOLOGY DEMONSTRATION PROJECT.

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5.2 *Identification of Respective Roles and Responsibilities*

DOE

The DOE shall be responsible for monitoring all aspects of the project and for granting or denying approvals required by this Cooperative Agreement. The DOE Contracting Officer is the authorized representative of the DOE for all matters related to the Cooperative Agreement.

The DOE Contracting Officer will appoint a COTR, who will be the authorized representative for all technical matters and will have the authority to issue "Technical Advice" that may do the following:

- o Suggest redirection of the Cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, and suggest pursuit of certain lines of inquiry that assist in accomplishing the Statement of Work.

- o Accept those reports, plans, and technical information required to be delivered by the Participant to the DOE under this Cooperative Agreement.

The DOE COTR does not have the authority to issue any technical advice that does the following:

- o Constitutes an assignment of additional work outside the Statement of Work.

- o In any manner causes an increase or decrease in the total estimated cost or in the time required for performance of the Cooperative Agreement.

- o Changes any of the terms, conditions, or specifications of the Cooperative Agreement.

- o Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

All technical advice shall be issued in writing by the DOE COTR.

Participant

The project team consists of the Passamaquoddy Tribe; Dragon Products Company; E.C. Jordan Company, a subsidiary of C-E Environmental, Inc.; HPD, Incorporated; and Cianbro Corporation. The Passamaquoddy Tribe, the Participant, invented and owns the technology and retains the responsibility for execution of the cooperative agreement. The Passamaquoddy Tribe, through a working group chaired by the Program Manager, will coordinate the project team members, provide technical expertise, and administer the project. The Dragon Products Company's senior management will be responsible for the demonstration plant operation during Phase III. The Dragon Products Company will also provide administrative and technical support to the project and will make available computer facilities and clerical and accounting assistance at the site. The plant laboratory will also be available to the project.

The Director of Research and Development of the Passamaquoddy Tribe's Department of Passamaquoddy Technology will serve as the Tribe's Clean Coal Technology Program Manager. In this capacity, he will be responsible for supervising project performance as outlined in the Cooperative Agreement.

The implementation of the Cooperative Agreement will be a joint effort between the Department of Passamaquoddy Technology and Dragon Products Company, Inc. The project will be managed by a working group comprising two tribal personnel-- the Director and Associate Director, Department of Passamaquoddy Technology-- and two Dragon personnel-- the President and Vice President-Finance & Administration. The Program Manager will chair this group. All subcontracts, design approvals, construction approvals, and financial disbursements will be subject to the authority of this working group.

The Program Manager will supervise preliminary and final design of the Recovery Scrubber. In addition, he will address the environmental and the technical reporting requirements of the DOE. The Associate Director will supervise business activities relevant to the design, construction, and financing of the project. In addition, he will address the financial and intellectual property reporting requirements of the DOE. The President of Dragon Products will supervise construction of the project through a general contractor, coordinating with the Program Manager in the event of design-related construction decisions. The Vice President of Dragon Products will assist in the supervision of construction and will supervise accounting and financial reporting for activities at the demonstration site as required during the construction and monitoring phases of the project.

Three additional organizations will play important roles in the implementation of the project: E.C. Jordan Company (Portland, Maine), a division of Combustion Engineering, will provide engineering services for the purpose of engineering the overall scrubber system; HPD, Incorporated (Naperville, Illinois) will engineer and oversee fabrication of the heat exchanger/crystallizer unit; and Cianbro Corporation (Pittsfield, Maine) will construct the Recovery Scrubber at the demonstration site.

5.3 Project Implementation and Control Procedures

All work to be performed under the Cooperative Agreement is divided into three phases. These phases and their expected durations are as follows:

Phase I. Design and Permitting (12 months)
Phase II. Construction and Start-up (13 months)
Phase III. Operation, Data Collection, Reporting, and Disposition (14 months)

Budget periods will be established. Consistent with P.L. 100-202 as amended by P.L. 100-446, DOE will obligate sufficient funds to cover its share of the cost for each budget period. Throughout the course of this project, reports dealing with the technical, management, cost, and environmental-monitoring aspects of the project will be prepared by the Tribe and provided to DOE.

5.4 Key Agreements Impacting Data Rights, Patent Waivers, and Information Reporting

The Participant's incentive to develop this technology is to realize profits from royalties and license agreements for the Recovery Scrubber technology. Successful demonstration of the Recovery Scrubber is expected to result in its widespread use in the cement industry.

The key agreements in respect to patents and data are the following:

- Standard data provisions are included, giving the Government the right to have delivered, and use with unlimited rights, all technical data first produced in the performance of the Agreement that does not disclose preexisting proprietary data of the Passamaquoddy Tribe.

- Proprietary data, with appropriate markings, may be required to be delivered to the Government. The Government has obtained sufficient rights to proprietary data and non-proprietary data to allow the Government to complete the project if the Participant withdraws.

- A patent waiver has been requested, which if granted by DOE would give the Passamaquoddy Tribe ownership of foreground inventions subject to the march-in-rights and U.S. preference found in P.L. 96-517.

5.5 Procedures for Commercialization of Technology

The Passamaquoddy Tribe intends to fully commercialize its proprietary and patented Recovery Scrubber. The first target market will be the cement industry, where the Passamaquoddy Tribe believes that it can sell and install approximately 184 Recovery Scrubbers over the next ten years.

These sales will be made possible by the full-scale demonstration project, financed by both the federal government and the Passamaquoddy Tribe at the Dragon Products Company plant in Thomaston, Maine. A marketing effort has already begun. However, it will accelerate in mid-1990 with visits to the Dragon site by prospective customers. In 1991, the system will be seen in full operation, and it is expected that this will lead to six orders, with contracts for delivery in 1992.

Prospective purchasers will be able to see that the sulfur removal efficiency is as good as, or better than, other scrubbers. Second, it will be clear that the process does not require the purchase of any outside material as a scrubber reactant. Third, it will be seen that there is no scrubber waste sludge, and that the landfill, which is normally required to receive kiln dust, has been eliminated from the operation. Fourth, the Recovery Scrubber has the additional *unique benefit of providing positive cash flow* at all *times as a result of the* by-product sales, a characteristic that is unique in flue gas desulfurization scrubbing systems.

The basis for the marketing of nearly all industrial equipment is user benefit and return on investment. The commercialization plan is founded on the user benefits described above and also on the fact that the Recovery Scrubber pays for itself in under four years depending on each plant's process and environmental conditions. No other sulfur dioxide scrubbing system in current use in the United States has the capability of paying for itself in any period. All presently utilized scrubbers are uncompensated added expenses. For all of these reasons, the Tribe is confident that commercialization of its Recovery Scrubber will be highly successful.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Base-Line Costs

The total estimated cost for this project is 10,165,916. The Participant's contribution and the Government share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
PRE-AWARD		
Government	520,907	47.08
Participant	585,522	52.92
PHASE I		
Government	322,471	47.08
Participant	362,471	52.92
PHASE II		
Government	3,256,525	47.08
Participant	3,660,535	52.92
PHASE III		
Government	686,178	47.08
Participant	771,307	52.92
TOTAL PROJECT		
Government	4,786,074	47.08
Participant	5,379,842	52.92
TOTAL	10,165,916	100.0

At the beginning of each budget period, DOE will obligate sufficient funds to pay its share of expenses for that budget period.

6.2 Milestone Schedule

Design and permitting activities are scheduled to be completed in 12 months. Construction and startup activities are scheduled to be completed in 13 months. Plant operations and reporting are scheduled for 14 months. Overall project duration is 36 months reflecting some overlap between design and construction activities.

The critical project tasks are identified and scheduled as shown in Figure 4.

6.3 Repayment Plan

Based on DOE's recoupment policy as stated in Section 6.4 of the PON, DOE is to recover an amount up to the Government's contribution to the project. The Passamaquoddy Tribe has agreed to repay the Government in accordance with the stated Recoupment/Repayment Plan to be included in the final negotiated Cooperative Agreement.

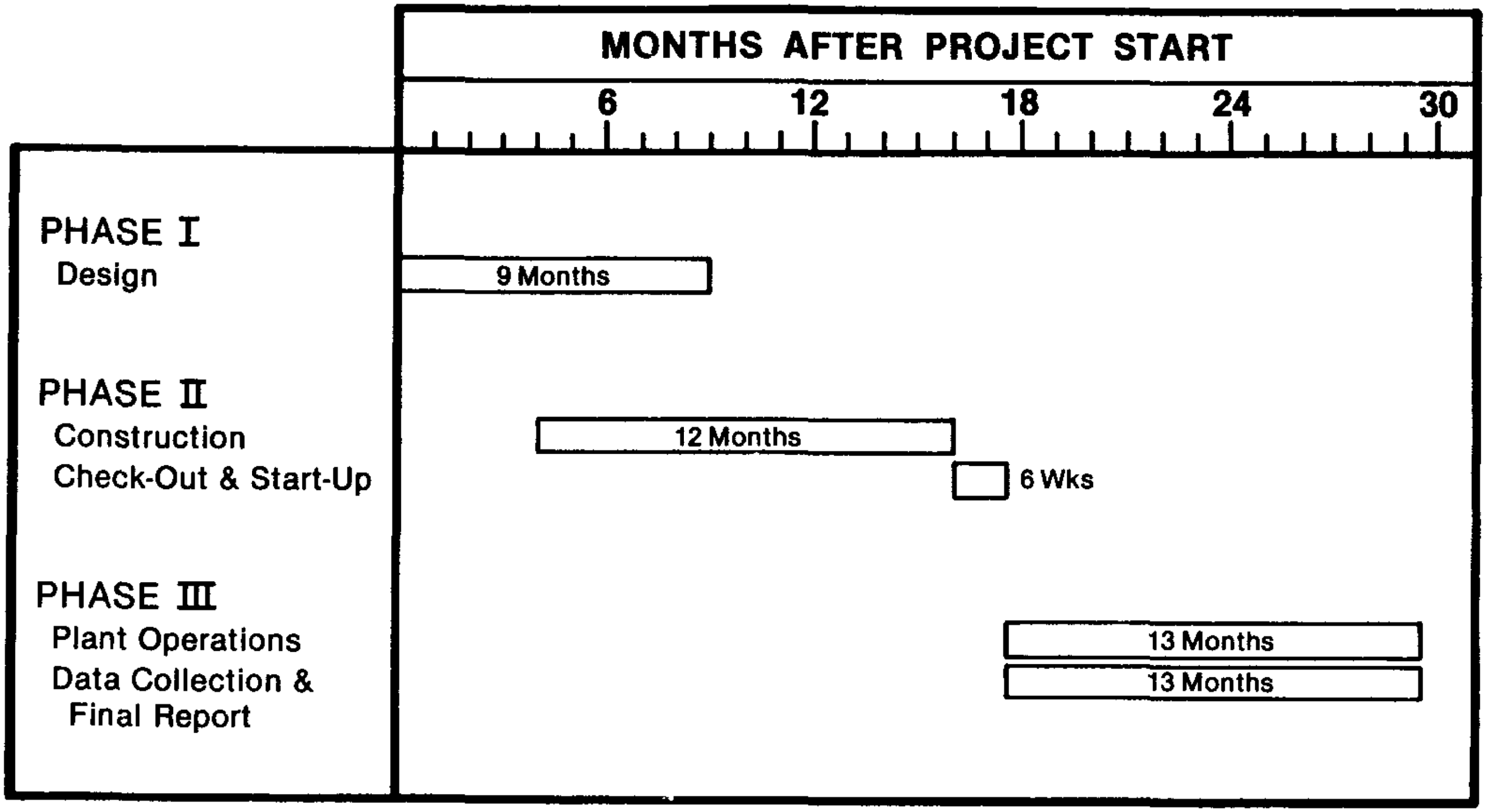

FIGURE 4. RECOVERY SCRUBBER PROJECT SCHEDULE.

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